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# **Heat Stress Management in Florida Department of Transportation Maintenance Activities**

**Final Report  
July 13, 1998**

## **Report Prepared for**

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Abstract  Heat stress is a combination of environmental conditions and work demands that is a common hazard in many outside workplaces. The purpose of this project was to characterize the potential heat stress exposures among roadway maintenance personnel in Florida's Department of Transportation and then make recommendations on managing any routine heat stress. Based on an analysis of environments and work demands, the crews could be significantly exposed over large segments of the year. Because of the exposures, general controls are necessary and include training, the implementation of heat stress hygiene practices, medical surveillance and a heat-alert program. During the hotter months, it will be necessary to employ specific controls for crews with moderate or high metabolic rates. While engineering controls should be considered the first, administrative controls are useful and include providing discretion over the pace of work, sharing difficult jobs, and rescheduling work to cooler parts of the day.			
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# **Heat Stress Management in Florida Department of Transportation Maintenance Activities**

## ***Executive Summary***

Heat stress is a combination of environmental conditions and work demands, and it can occur in a wide variety of circumstances. It is a common hazard in many workplaces in which the work is performed outside. Considering Florida's high temperatures and humidities as well as clear skies, it is to be expected. The resulting heat stress leads to more injuries and the risk of heat-related disorders.

The purpose of this project was to characterize the potential heat stress exposures among roadway maintenance personnel in Florida's Department of Transportation and then make recommendations on managing any routine heat stress that may be present. The project approach was to look for routine exposures that were likely to be high. The next step was to assess the metabolic demands and potential environmental conditions associated with the target jobs. With an understanding of the levels of heat stress that might be seen, decisions were made about how to control for them.

Using the Tampa Bay area as an average between north and south Florida, it can be expected that overall heat stress would be an issue in the summer months. Because extreme conditions can occur in the spring and fall, high humidity and record high temperatures were considered in the environmental scenarios. The crews would be significantly exposed during March through November. During the worst case, but rare, afternoons, it is likely most of the crews can be exposed in any month in Florida.

General controls should be implemented for the FDOT employees working outside. They include training, the implementation of heat stress hygiene practices, medical surveillance and a heat-alert program to notify employees of especially hot and humid conditions. Training should highlight the causes of heat stress and the body's responses; the signs and symptoms of heat-related disorders; and heat stress hygiene practices. Heat stress hygiene practices are the actions taken by an individual to reduce the risks of a heat disorder. The hygiene practices include fluid replacement, self-determination, lifestyle and diet, health status, and acclimation. Drinks should be provided to all employees, and commercial drinks have the advantage that more water is consumed with them. A heat alert notice trigger for the heaviest work would be a Heat Index of 86 °F.

During the hotter months in Florida, it will be necessary to employ specific controls for crews with moderate or high metabolic rates. While engineering controls are considered the first and preferable line of defense, administrative controls should be employed where engineering controls cannot. Administrative controls include providing discretion over the pace of work, sharing difficult jobs, and rescheduling work to cooler parts of the day. One of the most common administrative controls is work/rest cycles. For most jobs under most reasonable environmental conditions, the recovery times are small. Rather than instituting rigid specifications for work/rest cycles, some guidance was provided.

## **Heat Stress Management in Florida Department of Transportation Maintenance Activities**

### ***Introduction***

Heat stress is primarily a problem of removing heat that is generated inside of the body. As people work, they produce a series of chemical reactions called metabolism. While the metabolism supports muscle contractions and other physiological functions, most of the energy is released as heat inside the body. As the work demands increase, the metabolic rate also increases, which means the rate of internal heat generation also increases. This tends to increase core temperature. Hot air and radiant heat (eg, from the sun) also tend to raise body core temperature.

The body responds to the increase in metabolic rate and core temperature by increasing heart rate to move more blood from the inside of the body to the skin. Like an automobile engine cooling system, the blood moves heat from the core to the skin (which acts like a radiator). The added demand to move blood to the skin represents an additional cardiovascular demand to the work.

The best way to remove the heat from the skin is to evaporate sweat. Therefore, the sweat glands secrete water on to the skin to provide for the evaporative cooling. The body controls the rate of sweating to match the cooling requirements, until it reaches the greatest rate that it can support. As the humidity in the air increases, specifically the water vapor pressure and not relative humidity, the more difficult it becomes to evaporate sweat. The water lost as sweat must be replaced or the person will dehydrate.

Clothing also limits the ability to cool by sweat evaporation. Under most conditions, workers wear light-weight work clothing to minimize the effect clothing on heat stress. Sometimes protective clothing is required for special tasks like welding and pesticide application. Under these conditions, the clothing will add to the heat stress.

Because heat stress is a combination of environmental conditions, work demands and clothing requirements, the analysis must include these features. The environmental conditions are usually described by an temperature index called wet bulb globe temperature (WBGT). This index is greatly influenced by the humidity in the air along with sources of radiant heat like the sun or hot surfaces. Assuming ordinary work clothes, a threshold WBGT for any given work demand is available. This threshold is called the TLV (threshold limit value). The TLV can be lowered for other kinds of clothing requirements.

Heat stress can occur in a wide variety of circumstances. It is a common hazard in many workplaces in which the work is performed outside. Considering Florida's high



temperatures and humidities as well as clear skies, it is to be expected. The resulting heat stress leads to more injuries and the risk of heat-related disorders.

The purpose of this project was to characterize the potential heat stress exposures among roadway maintenance personnel in Florida's Department of Transportation and then make recommendations on managing any routine heat stress that may be present. The project approach was to look for routine exposures that were likely to be high. The next step was to assess the metabolic demands and potential environmental conditions associated with the target jobs. With an understanding of the levels of heat stress that might be seen, decisions can be made about how to control for them.

### ***Heat Stress Analysis***

After meetings with safety and supervisory personnel at District 1 and 7 offices, a group of jobs was identified as being more likely associated with heat stress than other routine jobs. These jobs were studied further to estimate the metabolic rate of doing the work and what the environmental conditions might be. (The complete study is described by Dennis Milak in his masters thesis, which was supplied to FDOT as a progress report.)

The target jobs are listed in Table 1. The metabolic rate was estimated at two-minute intervals and then averaged over an hour. The highest one-hour average metabolic rate is shown in the table for job. The units are watts. The next column gives the TLV in °C for each of the activities based on the highest hourly metabolic rate. Finally, typical activities in the job during the time the metabolic rate was estimated are provided.

**Table 1**  
**Estimated Metabolic Rates and the WBGT TLV**

CREW	Highest 1-hour Metabolic Rate (W)	WBGT TLV (°C)	Typical Tasks
Sod Crew	550	25	shoveling, spreading dirt
Light Mowing Crew	540	25	pushing motorized mower
Asphalt Crew	370	27	shoveling, spreading asphalt
Mud-jacking Crew	330	28	shoveling, sweeping, jack-hammering
Sign Crew	220	30	digging holes, carrying signs
Hvy. Mowing Crew	120	33	riding mower

The metabolic rate estimation showed that the sod and light mowing crews had the highest 1-hour average metabolic demands, 550 and 540 watts respectively. These crews maintained high physical work demands over the longest periods of time. For the sod crew, shoveling dirt, spreading soil and throwing sod were the largest contributors to the

overall metabolic rate. The light mowing crew was required to push a lawn mower over a long period of time while walking at a moderate pace with few breaks. These should be taken as typical of heavy work demands.

The mud jacking and asphalt crews had metabolic rates of 330 and 380 watts, respectively. These crews worked primarily on road surfaces. The mud jacking crew used a jack-hammer to create holes in the concrete, swept up debris, and mixed and injected cement. The asphalt crew was required to carry, spread and tamp down asphalt. These were assigned to the moderate category of work demands.

The sign crew, although it did perform physical tasks, had a lower 1-hour average of 220 watts. The sign crew job tasks did not take as long to complete and the crew traveled from place to place allowing for recovery between tasks. Digging the holes for the sign posts and handling the signs with the posts were the most demanding tasks. The heavy mowing crew also had a low average of 120 watts. Both the sign and heavy mowing crew work can be classified as light work.

With three categories of work described by the jobs that were sampled, environmental limits based on WBGT can be assigned. These were 25, 28 and 30°C-WBGT. So whenever the environmental conditions exceeded these values, heat stress may be a factor in the job.

The next step was to find whether the environmental conditions were high enough to describe any of these jobs as above the heat stress threshold. To do this, a model of environmental conditions was developed that related actual conditions to climatic data reported by the National Weather Service. (See Milak thesis for details.) Four climatic scenarios were considered:

- Normal Afternoons: normal high temperature/normal humidity
- Very Humid Afternoons: normal high temperature/high humidity (95%ile)
- Record Hot Afternoons: record high temperature/normal humidity
- Worst Case (rare event): record high temperature/very high humidity

The estimated monthly WBGTs for the four scenarios were determined. They were compared to the TLV for each crew to determine if the estimated conditions would place the employee above the TLV. As expected, the jobs with higher metabolic rates (light mowing and sod) had the broadest band of months (April through October). The lightest work would normally be above the TLV only in July and August, and the moderate work from May through October. When especially humid days occur, the band of months in which the crew may be above the TLV increases. These months extend the normal bands by one or two months. When record high temperatures were considered, the band of months in which work may occur above the TLV increases yet again. For the high metabolic rates, virtually every month may have a day above the TLV if a record hot day is encountered. For the heavy mowing (lowest metabolic rate), the band for record hot days is still the smallest, ranging from May through October. Under the rare conditions

of a combination of record high temperature and very high humidity, there is almost no exception to the work being above the TLV.

Acclimatized workers should be able to work at or somewhat above the TLV if they have been included in a heat stress program. Therefore, the months when the work would place the employee significantly above the TLV by 3 °C were considered. In general, the 3 °C margin above the TLV reduces the inclusion bands considerably. The implication is that the heavy and moderate metabolic rates need special consideration beyond general heat stress controls from May through October in central Florida.

To generalize the results to south and north Florida, readily available climatic data would be important. For this reason, the Heat Index announced by the local National Weather Service stations would be a better index of convenience than WBGT. As described below, the Heat Index can be used to alert crews when extra diligence is required and work/recovery periods considered.

### ***Recommendations***

The TLV's were used with the environmental scenarios to determine which crews would have a significant risk for heat stress and which months it could be expected for that to occur. Using the Tampa Bay area as an average between north and south Florida, it can be expected that overall heat stress would be an issue in the summer months. Because extreme conditions can occur in the spring and fall, high humidity and record high temperatures were considered in the environmental scenarios. It can be expected that very humid conditions may occur a few times throughout the year. It can also be expected that record high temperatures may not be experienced in a calendar year and may only occur during heat wave conditions.

Assuming that an acclimated worker covered by a good heat stress management program can safely work above the TLV by 3 °C, a substantial exposure to heat stress should be expected when the environmental WBGT is 3 °C above the TLV. Based on the metabolic rates and environmental scenarios, the sod and light mowing crews showed the highest risk for heat stress. During the worst case afternoons (the rare occurrence of a record temperature with very high humidity), it is likely most of the crews will be above the TLV for all months in Florida. More likely, the crews would be significantly above the TLV sometime during the hotter months in Florida, March through November.

Under normal conditions or very humid conditions, the months of April through November would be of concern for the crews with the highest average metabolic rates. The light mowing, sod, asphalt, and mud jacking crews were significantly above the TLV during the months of May through October. Due to their lower metabolic rates, the sign repair crews and heavy mowing crews were not significantly above the TLV throughout the year for normal and extremely humid conditions.

The FDOT crews that were selected should all be placed into a Heat Stress Program based upon the findings of this study. By extension, all maintenance workers should be included.

## **General Controls**

General controls should be implemented for the FDOT employees working outside. General controls should include training, the implementation of heat stress hygiene practices, medical surveillance and the implementation of heat-alert programs to notify employees of especially hot and humid conditions.

Training should highlight the causes of heat stress and the body's responses; the signs and symptoms of heat-related disorders; and heat stress hygiene practices. A package of slides and discussion points has been prepared to aid FDOT safety personnel with training for heat stress. (This package was provided as a separate progress report.)

Heat stress hygiene practices are the actions taken by an individual to reduce the risks of a heat disorder. While the individual is responsible for practicing good heat stress hygiene, FDOT provides the information through training and helps the workers practice them. The hygiene practices include fluid replacement, self-determination, lifestyle and diet, health status, and acclimation.

*Fluid Replacement.* A great deal of water is lost from the body as sweat for evaporative cooling. Losses may be up to 6 quarts of water in one day. This water should be replaced by drinking cool water or flavored drinks (e.g., dilute iced tea, artificially sweetened lemonade, or commercial fluid replacement drinks). Because thirst is not a sufficient driver for water replacement, workers should drink small quantities as frequently as possible. This helps instill drinking as a habit and the volumes do not cause discomfort. If work is to be performed in a drinking-restricted area, drinking about one pint per hour of work before the work begins will help meet the demands for water during the work.

As a special note, the question of providing commercial drinks is often raised. It is clear that workers who are offered commercial drinks will replace more water than those who do not have it available. Therefore, there is considerable advantage to providing these drinks over water in terms of reducing the risk of dehydration.

*Self-determination.* One aspect of self-determination is limiting an exposure to heat stress. It is a responsibility of the worker and supervision. In self-determination, the person seeks some relief from heat stress at the first symptom of a heat-related disorder or with extreme discomfort. Serious injury can occur if the onset of symptoms is ignored.

Another aspect of self-determination is reducing the effects of heat stress by lowering peak work demands and making the work demands lighter. For instance, when a fixed amount of work is assigned to a portion of the shift, peak demands can be reduced by leveling the work effort out over the allocated time or taking more frequent breaks. For those working in crews, the pace should consider the least heat-tolerant worker.

*Life Style and Diet.* A healthy lifestyle is important to lowering the risk of a heat-related disorder. A worker should have adequate sleep and a good diet. Exercise helps. A healthy lifestyle also means no abuse of alcohol or drugs, which have been implicated in heat strokes. In addition, exposures to heat stress immediately prior to work may increase the risk of a heat disorder at work.

A well-balanced diet is important to maintain the good health needed to work under heat stress. Large meals should not be eaten during work breaks because they increase circulatory load and metabolic rate. Diets designed to lose weight should be directed by a physician who understands that the patient is working under conditions of potential heat stress. Weight control for over-weight workers is recommended because obesity increases the risk of heat-related disorders. Salt intake as part of a normal diet is usually sufficient to meet the salt demands during heat stress work. Added salt may be desirable when repeated heat stress exposures are first experienced (i.e., during acclimation). If salt is restricted by a physician's order, the physician should be consulted.

*Health Status.* All workers should recognize that chronic illnesses, such as heart, lung, kidney, or liver disease, indicate a potential for lower heat tolerance and therefore an increased risk of experiencing a heat-related disorder during heat stress exposures. As a matter of principle, workers suffering from any chronic disorder should inform the physician of occupational exposures to heat stress and seek advice about the potential effects of the disorder or drugs used to treat it.

If a worker is experiencing the symptoms of any acute illness and still reports to work, that worker should inform the immediate supervisor.

*Acclimation.* Acclimation is the adaptation of the body to prolonged daily heat stress exposures. The ability to work increases and the risk of heat disorders decreases with acclimation. Acclimation is lost when there are no heat exposures. The loss is accelerated when an illness occurs. The process should be recognized and expectations adjusted. Workers will be able to work better after several days of heat exposures and they should expect less of themselves in the early days.

Medical surveillance and pre-placement physicals should be employed for the crews with the highest average metabolic rates. Pre-placement physicals can determine if the employee is at a higher risk for heat-related illnesses. Precautions can be taken before the employee begins to work in the hot environment. Monitoring injury and illness data can help determine when heat-related illnesses are occurring, and controls can be employed.

Finally, a heat alert process should be instituted. This will alert supervisors and crews to when specific work practices need to be implemented. A useful trigger for the alert is the anticipated Heat Index from the National Weather Service and reported on local media outlets. The Heat Index is directly available to most districts. A good trigger point would be the point at which heavy work would be more than 3 °C-WBGT above the TLV; that is, the environmental conditions would be greater than 28 °C-WBGT. The equivalent Heat Index would be 30 °C or 86 °F.

### **Specific Controls**

Specific controls such as engineering controls, administrative controls and personal protective equipment should be employed when the workers are significantly above the TLV by 3 °C or more. During the hotter months in Florida, it will be necessary to employ specific controls for crews with moderate or high metabolic rates.

Engineering controls are considered the first and preferable line of defense. For highly mobile maintenance crews, they may be problematic. Examples of engineering controls are changes to the work, such as using more powered equipment and less manual labor. A heat guard could be installed on the tractors to reduce radiant and convective heat from the motors. Opportunities to reduce solar heat load by shielding should also be considered.

Administrative controls should be employed where engineering controls cannot. Administrative controls include providing discretion over the pace of work, sharing difficult jobs, and rescheduling work during cooler parts of the day. Scheduling work at night could significantly reduce the risk of heat stress due to lower temperatures. During breaks, the worker should get out of the sun. Recovering in an air-conditioned truck or under a shade tree can help considerably.

One of the most common administrative controls is work/rest cycles. Work rest cycles are recommended by the ACGIH as a way to lower the average metabolic demands. Ideally, the metabolic rates should be lowered enough to bring the exposure down to the TLV. More practically, they should bring the difference above the TLV below 3 °C. Work-Rest Cycles were estimated to determine a rest time that would bring the worker within 3 °C of the TLV. For most jobs under most reasonable environmental conditions, the recovery times are small. The worst case environment for the heaviest work was 35 min of work should be balanced by 25 min of recovery. Rather than instituting rigid specifications for work/rest cycles, these estimations can be used for guidance to the supervisors on work output expectations and to the crews under the principle of self-determination of pace and duration.

Personal cooling should not be needed under any ordinary and routine work. If special work situations may arise, advice on personal cooling can be provided by USF.

***Bibliography***

American Conference of Governmental Industrial Hygienists (ACGIH): Threshold limit values and biological exposure indices for 1998. Cincinnati: ACGIH, 1998.

Bernard, T. E. Thermal Stress. In Plog, B (ed), *Fundamentals in Industrial Hygiene*, 4th ed. Chicago: National Safety Council, 1995.

Bernard, T. E., F. N. Dukes-Dobos and J. D. Ramsey. Evaluation and control of hot working environments: Part II – Knowledge base for guide. *International Journal of Industrial Ergonomics* 14:129-138, 1994.

Milak, D. C.: Heat Stress Characteristics of Road Crews. MSPH Thesis, University of South Florida, 1998.

National Institute for Occupational Safety and Health (NIOSH): Criteria for a recommended standard...Occupational exposure to hot environments. Revised criteria 1986. USDHHS (NIOSH) 86-113, Wash, DC (1986).

Ramsey, J. D., F. N. Dukes-Dobos and T. E. Bernard. Evaluation and control of hot working environments: Part I – Guidelines for the practitioner. *International Journal of Industrial Ergonomics* 14:119-127, 1994.





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The purpose of this project was to characterize the potential heat stress exposures among roadway maintenance personnel in Florida's Department of Transportation and then make recommendations on managing any routine heat stress that may be present. The project approach was to look for routine exposures that were likely to be high. The next step was to assess the metabolic demands and potential environmental conditions associated with the target jobs. With an understanding of the levels of heat stress that might be seen, decisions were made about how to control for them.

Using the Tampa Bay area as an average between north and south Florida, it can be expected that overall heat stress would be an issue in the summer months. Because extreme conditions can occur in the spring and fall, high humidity and record high temperatures were considered in the environmental scenarios. The crews would be significantly exposed during March through November. During the worst case, but rare, afternoons, it is likely most of the crews can be exposed in any month in Florida.

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The next step was to find whether the environmental conditions were high enough to describe any of these jobs as above the heat stress threshold. To do this, a model of environmental conditions was developed that related actual conditions to climatic data reported by the National Weather Service. (See Milak thesis for details.) Four climatic scenarios were considered:

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The estimated monthly WBGTs for the four scenarios were determined. They were compared to the TLV for each crew to determine if the estimated conditions would place the employee above the TLV. As expected, the jobs with higher metabolic rates (light mowing and sod) had the broadest band of months (April through October). The lightest work would normally be above the TLV only in July and August, and the moderate work from May through October. When especially humid days occur, the band of months in which the crew may be above the TLV increases. These months extend the normal bands by one or two months. When record high temperatures were considered, the band of months in which work may occur above the TLV increases yet again. For the high metabolic rates, virtually every month may have a day above the TLV if a record hot day is encountered. For the heavy mowing (lowest metabolic rate), the band for record hot days is still the smallest, ranging from May through October. Under the rare conditions

of a combination of record high temperature and very high humidity, there is almost no exception to the work being above the TLV.

Acclimatized workers should be able to work at or somewhat above the TLV if they have been included in a heat stress program. Therefore, the months when the work would place the employee significantly above the TLV by 3 °C were considered. In general, the 3 °C margin above the TLV reduces the inclusion bands considerably. The implication is that the heavy and moderate metabolic rates need special consideration beyond general heat stress controls from May through October in central Florida.

To generalize the results to south and north Florida, readily available climatic data would be important. For this reason, the Heat Index announced by the local National Weather Service stations would be a better index of convenience than WBGT. As described below, the Heat Index can be used to alert crews when extra diligence is required and work/recovery periods considered.

### ***Recommendations***

The TLV's were used with the environmental scenarios to determine which crews would have a significant risk for heat stress and which months it could be expected for that to occur. Using the Tampa Bay area as an average between north and south Florida, it can be expected that overall heat stress would be an issue in the summer months. Because extreme conditions can occur in the spring and fall, high humidity and record high temperatures were considered in the environmental scenarios. It can be expected that very humid conditions may occur a few times throughout the year. It can also be expected that record high temperatures may not be experienced in a calendar year and may only occur during heat wave conditions.

Assuming that an acclimated worker covered by a good heat stress management program can safely work above the TLV by 3 °C, a substantial exposure to heat stress should be expected when the environmental WBGT is 3 °C above the TLV. Based on the metabolic rates and environmental scenarios, the sod and light mowing crews showed the highest risk for heat stress. During the worst case afternoons (the rare occurrence of a record temperature with very high humidity), it is likely most of the crews will be above the TLV for all months in Florida. More likely, the crews would be significantly above the TLV sometime during the hotter months in Florida, March through November.

Under normal conditions or very humid conditions, the months of April through November would be of concern for the crews with the highest average metabolic rates. The light mowing, sod, asphalt, and mud jacking crews were significantly above the TLV during the months of May through October. Due to their lower metabolic rates, the sign repair crews and heavy mowing crews were not significantly above the TLV throughout the year for normal and extremely humid conditions.

The FDOT crews that were selected should all be placed into a Heat Stress Program based upon the findings of this study. By extension, all maintenance workers should be included.

### **General Controls**

General controls should be implemented for the FDOT employees working outside. General controls should include training, the implementation of heat stress hygiene practices, medical surveillance and the implementation of heat-alert programs to notify employees of especially hot and humid conditions.

Training should highlight the causes of heat stress and the body's responses; the signs and symptoms of heat-related disorders; and heat stress hygiene practices. A package of slides and discussion points has been prepared to aid FDOT safety personnel with training for heat stress. (This package was provided as a separate progress report.)

Heat stress hygiene practices are the actions taken by an individual to reduce the risks of a heat disorder. While the individual is responsible for practicing good heat stress hygiene, FDOT provides the information through training and helps the workers practice them. The hygiene practices include fluid replacement, self-determination, lifestyle and diet, health status, and acclimation.

*Fluid Replacement.* A great deal of water is lost from the body as sweat for evaporative cooling. Losses may be up to 6 quarts of water in one day. This water should be replaced by drinking cool water or flavored drinks (e.g., dilute iced tea, artificially sweetened lemonade, or commercial fluid replacement drinks). Because thirst is not a sufficient driver for water replacement, workers should drink small quantities as frequently as possible. This helps instill drinking as a habit and the volumes do not cause discomfort. If work is to be performed in a drinking-restricted area, drinking about one pint per hour of work before the work begins will help meet the demands for water during the work.

As a special note, the question of providing commercial drinks is often raised. It is clear that workers who are offered commercial drinks will replace more water than those who do not have it available. Therefore, there is considerable advantage to providing these drinks over water in terms of reducing the risk of dehydration.

*Self-determination.* One aspect of self-determination is limiting an exposure to heat stress. It is a responsibility of the worker and supervision. In self-determination, the person seeks some relief from heat stress at the first symptom of a heat-related disorder or with extreme discomfort. Serious injury can occur if the onset of symptoms is ignored.

Another aspect of self-determination is reducing the effects of heat stress by lowering peak work demands and making the work demands lighter. For instance, when a fixed amount of work is assigned to a portion of the shift, peak demands can be reduced by leveling the work effort out over the allocated time or taking more frequent breaks. For those working in crews, the pace should consider the least heat-tolerant worker.

*Life Style and Diet.* A healthy lifestyle is important to lowering the risk of a heat-related disorder. A worker should have adequate sleep and a good diet. Exercise helps. A healthy lifestyle also means no abuse of alcohol or drugs, which have been implicated in heat strokes. In addition, exposures to heat stress immediately prior to work may increase the risk of a heat disorder at work.

A well-balanced diet is important to maintain the good health needed to work under heat stress. Large meals should not be eaten during work breaks because they increase circulatory load and metabolic rate. Diets designed to lose weight should be directed by a physician who understands that the patient is working under conditions of potential heat stress. Weight control for over-weight workers is recommended because obesity increases the risk of heat-related disorders. Salt intake as part of a normal diet is usually sufficient to meet the salt demands during heat stress work. Added salt may be desirable when repeated heat stress exposures are first experienced (i.e., during acclimation). If salt is restricted by a physician's order, the physician should be consulted.

*Health Status.* All workers should recognize that chronic illnesses, such as heart, lung, kidney, or liver disease, indicate a potential for lower heat tolerance and therefore an increased risk of experiencing a heat-related disorder during heat stress exposures. As a matter of principle, workers suffering from any chronic disorder should inform the physician of occupational exposures to heat stress and seek advice about the potential effects of the disorder or drugs used to treat it.

If a worker is experiencing the symptoms of any acute illness and still reports to work, that worker should inform the immediate supervisor.

*Acclimation.* Acclimation is the adaptation of the body to prolonged daily heat stress exposures. The ability to work increases and the risk of heat disorders decreases with acclimation. Acclimation is lost when there are no heat exposures. The loss is accelerated when an illness occurs. The process should be recognized and expectations adjusted. Workers will be able to work better after several days of heat exposures and they should expect less of themselves in the early days.

Medical surveillance and pre-placement physicals should be employed for the crews with the highest average metabolic rates. Pre-placement physicals can determine if the employee is at a higher risk for heat-related illnesses. Precautions can be taken before the employee begins to work in the hot environment. Monitoring injury and illness data can help determine when heat-related illnesses are occurring, and controls can be employed.

Finally, a heat alert process should be instituted. This will alert supervisors and crews to when specific work practices need to be implemented. A useful trigger for the alert is the anticipated Heat Index from the National Weather Service and reported on local media outlets. The Heat Index is directly available to most districts. A good trigger point would be the point at which heavy work would be more than 3 °C-WBGT above the TLV; that is, the environmental conditions would be greater than 28 °C-WBGT. The equivalent Heat Index would be 30 °C or 86 °F.

### **Specific Controls**

Specific controls such as engineering controls, administrative controls and personal protective equipment should be employed when the workers are significantly above the TLV by 3 °C or more. During the hotter months in Florida, it will be necessary to employ specific controls for crews with moderate or high metabolic rates.

Engineering controls are considered the first and preferable line of defense. For highly mobile maintenance crews, they may be problematic. Examples of engineering controls are changes to the work, such as using more powered equipment and less manual labor. A heat guard could be installed on the tractors to reduce radiant and convective heat from the motors. Opportunities to reduce solar heat load by shielding should also be considered.

Administrative controls should be employed where engineering controls cannot. Administrative controls include providing discretion over the pace of work, sharing difficult jobs, and rescheduling work during cooler parts of the day. Scheduling work at night could significantly reduce the risk of heat stress due to lower temperatures. During breaks, the worker should get out of the sun. Recovering in an air-conditioned truck or under a shade tree can help considerably.

One of the most common administrative controls is work/rest cycles. Work rest cycles are recommended by the ACGIH as a way to lower the average metabolic demands. Ideally, the metabolic rates should be lowered enough to bring the exposure down to the TLV. More practically, they should bring the difference above the TLV below 3 °C. Work-Rest Cycles were estimated to determine a rest time that would bring the worker within 3 °C of the TLV. For most jobs under most reasonable environmental conditions, the recovery times are small. The worst case environment for the heaviest work was 35 min of work should be balanced by 25 min of recovery. Rather than instituting rigid specifications for work/rest cycles, these estimations can be used for guidance to the supervisors on work output expectations and to the crews under the principle of self-determination of pace and duration.

Personal cooling should not be needed under any ordinary and routine work. If special work situations may arise, advice on personal cooling can be provided by USF.



***Bibliography***

American Conference of Governmental Industrial Hygienists (ACGIH): Threshold limit values and biological exposure indices for 1998. Cincinnati: ACGIH, 1998.

Bernard, T. E. Thermal Stress. In Plog, B (ed), *Fundamentals in Industrial Hygiene*, 4th ed. Chicago: National Safety Council, 1995.

Bernard, T. E., F. N. Dukes-Dobos and J. D. Ramsey. Evaluation and control of hot working environments: Part II – Knowledge base for guide. *International Journal of Industrial Ergonomics* 14:129-138, 1994.

Milak, D. C.: Heat Stress Characteristics of Road Crews. MSPH Thesis, University of South Florida, 1998.

National Institute for Occupational Safety and Health (NIOSH): Criteria for a recommended standard...Occupational exposure to hot environments. Revised criteria 1986. USDHHS (NIOSH) 86-113, Wash, DC (1986).

Ramsey, J. D., F. N. Dukes-Dobos and T. E. Bernard. Evaluation and control of hot working environments: Part I – Guidelines for the practitioner. *International Journal of Industrial Ergonomics* 14:119-127, 1994.

